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MAGNETIC TRAP**

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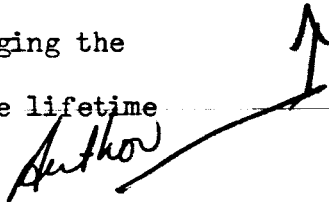
CERTAIN NEW RESULTS ON PLASMA CONFINEMENT IN A
MAGNETIC TRAP*

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Tentative results on preventing the escape of plasma from a magnetic trap, by modifying the field configuration through superposition of an auxiliary conductor field, are reported with comparative oscillograms for the flux of neutral particles with and without an additional field. An auxiliary field will eliminate the extensive pulsations of plasma density near the walls of the trap, by preventing groove-type plasma instabilities. The plasma lifetime is increased by enlarging the auxiliary field up to saturation, after which the lifetime depends only on the hydrogen pressure.

Author 

To prevent escape of the plasma, as mentioned in my last paper (CN-10/216), we attempted to modify the configuration of the field so as to obtain an increase in the field intensity (from the center of the trap) not only in a longitudinal but also in a radial direction, without disturbing the adiabatic properties of the trap. We superimposed on the main field another field from a system of conductors. Since the currents in adjacent conductors are in opposite directions, the field has a geometry of the same type as in hyperbolic traps. The field of such a system does increase along the radius, but the lines of force

* Report CN-10/262, presented to the Conference by the rapporteur M.S.Ioffe, has been printed from the sound recording. The discussion in English will be found on p.1108. A translation of the notes is at the end of this volume.

** Numbers in the margin indicate pagination in the original foreign text.

passing beyond the axis are curved to intersect the sidewall of the chamber. It is therefore necessary to provide "wall stoppers" by making the field of the conductors so large that the particles are reflected as they are at the ends of the trap. These results are entirely preliminary and show that, by changing the configuration of the magnetic field, considerable influence can be exerted on the instabilities that were noted in our earlier experiments.

(Editorial Note)

I should like to report on several experiments with a new configuration of the magnetic field of a trap with stoppers. These experiments were started only quite recently, so that the results are purely preliminary.

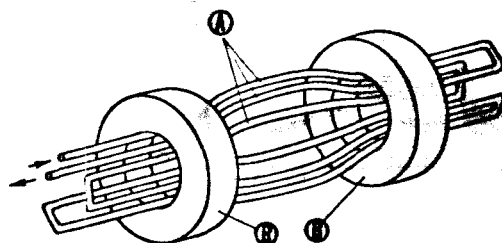


Fig.1 Scheme of Formation of Magnetic Field

As mentioned in my paper on Tuesday*, we noted distinctly in our earlier experiments that the plasma escaped from the trap across the magnetic field. The experimental data on this subject give grounds for considering that this escape is due to the groove-type instabilities that may occur in fields which fall off with increasing distance outward from the plasma boundary.

With this in mind, we attempted to modify the configuration of the field so as to have the field intensity increase from the center of the trap not only

* Paper CN-10/216: M.S.Ioffe and Ye.Ye.Yushmanov "Experimental Study of Plasma Instability in a Trap with Magnetic Stoppers", THIS SUPPLEMENT 1962, Part 1, p.177.

longitudinally but also radially, without substantially impairing the adiabatic properties of the trap.

Of the possible methods of establishing such a field, we selected the one schematically shown in Fig.1. In this scheme, coils are used to generate the

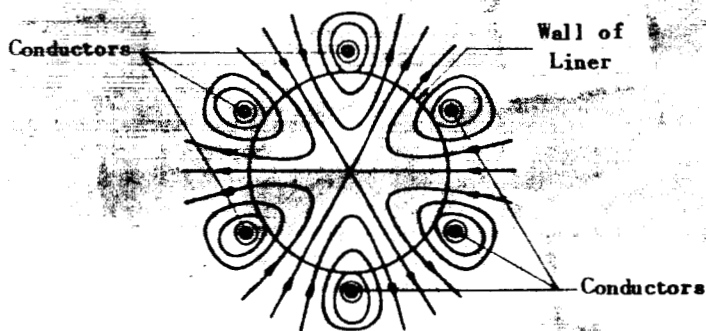


Fig.2 Geometry of the Magnetic Field

main longitudinal field with stoppers or plugs at the ends. We superposed this field with a field from a system of conductors with a current disposed along the lines of force of the main field around the axis of the trap. The current is passed in opposite directions through adjacent conductors, so that the resultant field has a geometry of the same type as in hyperbolic traps (Fig.2).

Here I should like to note that such field schemes have been considered at different times by various authors, for example by Grad et al. (Bibl.1) in a paper read before the Second Geneva Conference, by Golovin in his article published in Uspekhi Fiz. Nauk in 1961 (Bibl.2), and by Artsimovich in his recent book (Bibl.3) from which the diagrams in this paper have been taken.

Since the field of such a conductor system increases from the axis along the radius, it is possible, by passing a sufficient current through the conductors, to compensate the radial decline in intensity of the main field /1046

and cause that field to increase radially.

However, the following must be borne in mind. When the field of the conductors is superimposed on the main longitudinal field, the lines of force of the combined field assume a rather intricate shape. Only a relatively narrow

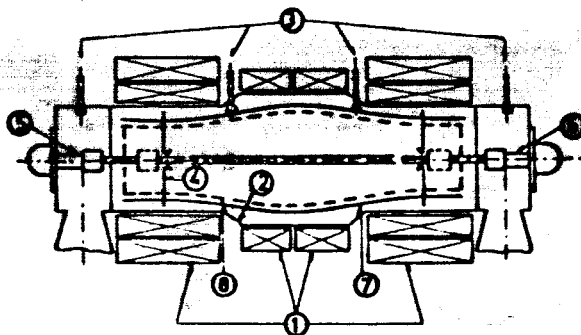


Fig.3 Schematic Sketch of Apparatus: 1 - Coil for generating the magnetic field; 2 - Vacuum chamber; 3 - Titanium vaporizers; 4 - Baffle; 5 - Plasma source; 6 - Receiving electrode; 7 - Conductors to generate additional field; 8 - Liner

bundle of lines of force near the axis will pass as before through the entire trap without striking the sidewalls. The lines of force that pass beyond the axis will be so curved that they will actually intersect the sidewall of the chamber. To prevent the particles moving along these lines of force from impinging on the walls, it is therefore obviously necessary to form, by the aid of conductors, so-called "wall stoppers" or plugs, i.e., to make the field of the conductors so large that particles approaching the wall will be reflected from the region of the intensified field as they are from the regions of the intensified field at the ends of the trap.

By analogy with the usual stopper relation $\alpha = H_w/H_0$, we can introduce the concept of a wall-stopper relation, defined as follows:

$$\alpha_{\text{wall}} = \frac{(H_0^2 + H_c^2)^{1/2}}{H_0}$$

where H_0 is the field intensity at the center of the trap and H_c the intensity of the field formed by the conductors at the points of intersection of the trap sidewalls by the lines of force.

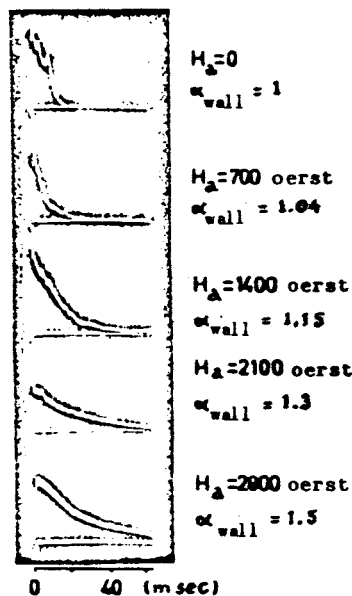


Fig.4 Oscillograms of the Neutral Particle Flux

This expression shows the factor by which the absolute value of the total field near the wall exceeds the field at the center of the trap.

The experiments were run with the same apparatus described in my last paper (Fig.3).

The conductors were fed by a current of up to 100 ka from a shock oscillator. The current has the shape of a damped sinusoid with a period of 40 msec. The maximum field intensity in the gap between the conductors is 3500-4000 gauss.

We measured the plasma lifetime as a function of the intensity of the additional field, holding all the other parameters constant. These parameters

were H_0 , U , p , and the operating conditions of the plasma source (U is the amplitude of the pulse of the accelerating potential and p the pressure of

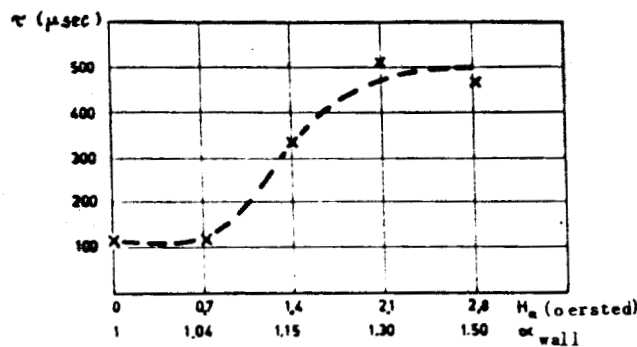


Fig.5 Plot of Correlation between Lifetime and Additional Field

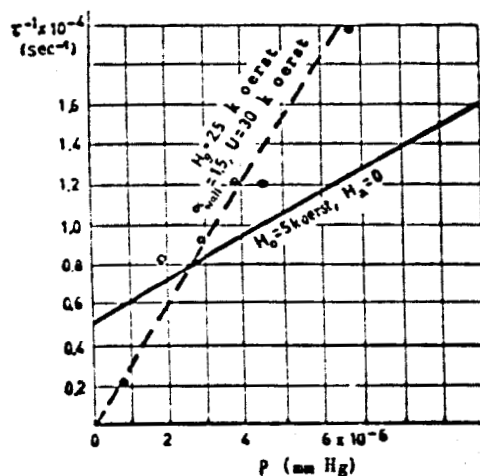


Fig.6 Plot of Correlation between Reciprocal Lifetime and Hydrogen Pressure

hydrogen in the chamber).

The lifetime was found from the time rate of decrement of the flux of fast neutral particles, obtained by charge exchange of the ions in the neutral gas.

Figure 4 shows oscillograms of the flux of neutral particles striking the

wall at various values of H_z .

Figure 5 gives the relation between the lifetime and H_z , found in working up the above oscillograms.

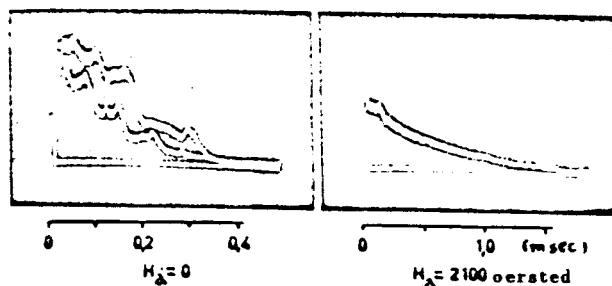


Fig.7 Oscillograms of Neutral Particle Flux with and without Additional Field

It is obvious that an increase in the additional field will cause an increase in the lifetime, by saturation at sufficiently large fields. It is suggested that the value of attainable τ in the region of saturation is now determined only by the mechanism of charge exchange and no longer by escape of the plasma from the trap as a result of instabilities. This is indicated by the dependence of the lifetime on the hydrogen pressure.

Figure 6 gives the relationship between the reciprocal lifetime and 1047 the hydrogen pressure in the range from 9×10^{-7} to 6×10^{-6} mm Hg. It will be seen from this diagram that the experimental values of $1/\tau$ cluster about a straight line which, on extrapolation to zero pressure, passes close to the origin of coordinates (broken line). This means that the losses not caused by charge exchange, if any such losses are still present, are small in comparison to the charge-exchange losses. The same diagram shows, for comparison, the curve of $1/\tau$ plotted against the pressure at $H_0 = 5000$ oersteds in the absence of an additional field.

In conclusion, we also present a comparison of the oscillograms of the neutral particle flux with and without an additional field (Fig.7).

In the case without an additional field, there are oscillations that indicate the steep pulsations in plasma density taking place near the wall of the trap.

In the case with an additional field, the curve is rather smooth, indicating the absence of such pulsations.

These are the experimental facts that can be established at present. They demonstrate that by changing the configuration of the magnetic field, a considerable influence can be exerted on the instabilities that we encountered in our previous experiments.

In conclusion, I should like to emphasize again that these results are entirely preliminary, and that they might be used as basis for formulating only a single definite conclusion, namely, that it is useful to carry on the work in this direction.

We express our thanks to Academician L.A.Artsimovich for his interest in this work and for his valuable advice and discussion.

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